

Conservative and Non-conservative Variability in the Inherent Optical Properties of Dissolved and Particulate Components in Seawater

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LONG TERM GOAL

The long term goals of this project are to identify and quantify the physical, chemical and biological mechanisms underlying variability in the inherent optical properties (IOPs). Once established, the inverse approach will be taken to predict physical, chemical and biological processes in the ocean using optical measurements.

OBJECTIVES

My approach to these goals is to develop methods for separating the IOPs into contributions by different functional groups in discrete size ranges. The functional groups (phytoplankton, organic and inorganic particles, dissolved material) are optically distinct. The optical properties for the different groups display variations due to unique mechanisms (i.e. growth, grazing, photoacclimation, photobleaching, degradation, aggregation) which operate on a range of time scales (i.e. minutes to weeks). Additionally, some of the mechanisms inducing optical variations operate selectively on different size ranges of material (i.e. taxon-specific growth/grazing, aggregation). Measuring the size/functional optical variations with respect to hydrographic variations allows the non-conservative variations (identified above) to be separated from the conservative variations associated with water mass dynamics (i.e. advection, mixing). In this manner, functional groups in discrete size ranges can be targeted as distinct tracers for a range of physical, biological and geochemical processes.

APPROACH

As part of the directed research initiative Coastal Mixing and Optics (CMO), two three-week cruises were undertaken in August-September 1996 and April-May 1997 to a single station on the continental shelf south of Nantucket (40°30' N, 70°30' W) in 65 m water depth. An integrated optical profiling system, consisting of three WETLabs ac9s (the third instrument kindly provided by Dr. Heidi Sosik of WHOI) and an FSI micro CTD, was deployed with the ship's CTD/rosette package to obtain optical measurements concurrent with discrete water samples. In situ fractionation of the IOPs was obtained by placing filter cartridges on the intake ports of the absorption and attenuation tubes. Discrete water samples were similarly size fractionated and analyzed for nutrients, pigment concentrations, particle composition, concentration, and size distribution, particulate and dissolved absorption coefficients. The particulate absorption coefficients were further separated into phytoplankton and colored particle contributions.

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WORK COMPLETED

Both cruises were successfully completed with over one hundred optical casts performed per cruise yielding over three profiles per day of at least three size classes of IOPs. All water sample analyses have been completed. All optical profiles have been processed: temperature and scattering corrections applied, outliers removed (and there were a lot of them), temporal lags applied. Statistical approaches such as empirical orthogonal function analysis of variance will be used to quantify covariance between optical and hydrographic fields. Temporal and spatial decorrelation scales will be assessed.

RESULTS

The water column encountered during the summer cruise was characterized by highly stratified conditions compared to the spring cruise which captured the onset of stratification (Fig. 1). The attenuation coefficient, c , was significantly greater during stable summer conditions than during the springtime. Bottom water maxima were dominated by scattering, b , to a greater degree than in the overlying waters. Subsurface and surface absorption, a , maxima were observed, respectively, during stable and unstable conditions. During both periods, a clear midwater zone was observed (35 to 55 m). The large scale variations in a , b and c appear to be coherent with density although copious small scale variations were not conservative.

Only by separating the absorption into phytoplankton, colored particulate material (CPM) and colored dissolved organic material (CDOM) components and into discrete size ranges can the shorter scale variations in the optical properties be elucidated. In the highly stratified summer waters (Fig. 2) the subsurface turbidity maximum is dominated by phytoplankton which exhibit a shift in size range from $>10\mu\text{m}$ at 20 m to a population dominated by 5 to 10 μm cells 35 m depth to a $<5\mu\text{m}$ population at 20 m depth. Absorption by CPM was generally very low except for the substantial signature of larger, $>10\mu\text{m}$, suspended particles in the benthic boundary layer associated with the passage of Hurricane Edouard. Absorption by CDOM exhibited diel variations in the surface layer associated with daytime photooxidation and nighttime mixing. Mid and deep water maxima were associated with slope water and resuspension, respectively. Optical variations during the onset of stratification were dominated by the phytoplankton component (Fig. 3). Cells were much smaller during this period and mini-blooms in the surface waters were coherent with stratification/ destratification events on a 2 to 3 day time scale.

IMPACT/APPLICATION

Our ability to separate IOPs into size fractionated components provides the means to understand conservative and non-conservative optical variations. These components exhibit variations on distinct time and space scales due to specific mechanisms and thus become tracers for a variety of physical biological, chemical and geological processes.

TRANSITIONS

The techniques and results developed in this program are being applied to 3D optical data collected with a SeaSoar, results will be presented at the Ocean Sciences Meeting in Feb. 2000 (Simeon, Barth and Roesler).

RELATED PROJECTS

1- We used a similar approach to investigate phytoplankton variability in the equatorial Pacific as part of the JGOFS Zonal Flux study (Simeon, Roesler et al.).

2- We are using this technique to separate toxic algal cells from the community during red tide blooms in the Benguela Upwelling Current (Roesler, Etheridge et al.).

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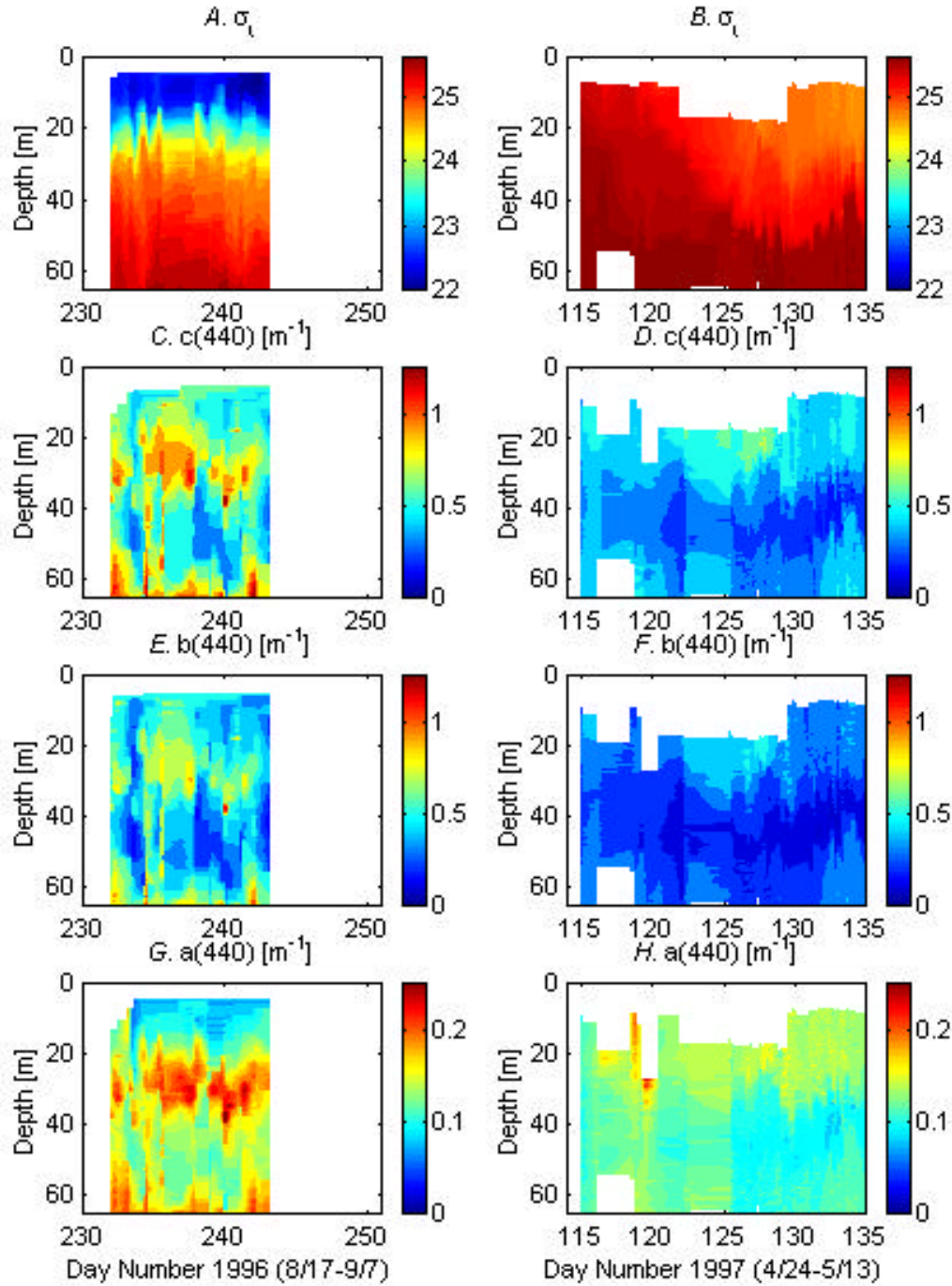


Figure 1. Hydrographic and optical properties of the CMO station during the highly stratified summer conditions (left panel) and during the onset of stratification in the spring (right panel): density (A, B), attenuation (C, D), scattering (E, F), and absorption (G, H). Optical coefficients at 440 nm measured in situ with ac9s. Missing values due to weather and bubble injection into surface waters.

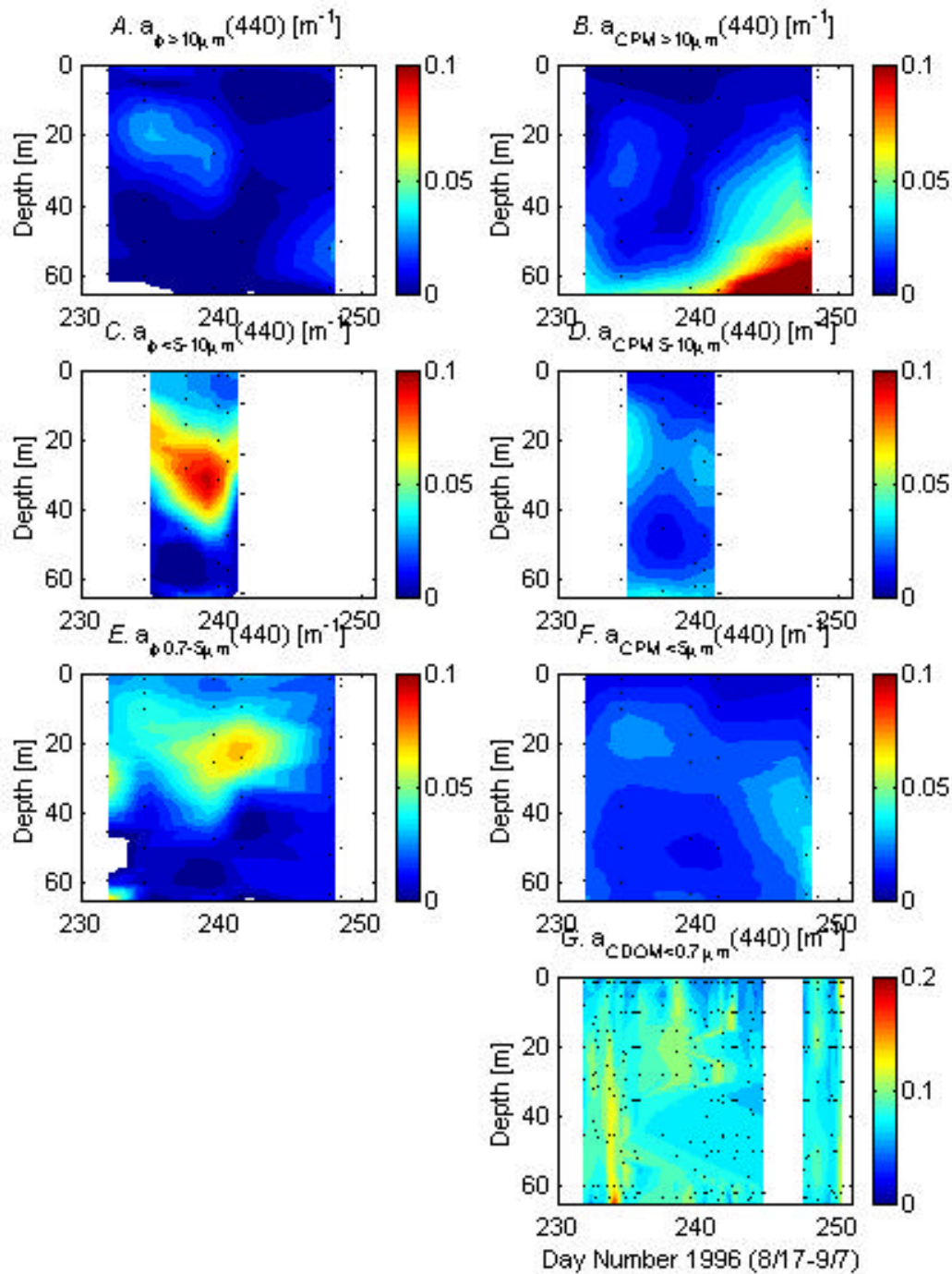


Figure 2. Size fractionated phytoplankton(left panel) and colored particulate and dissolved material (right panel) absorption at the CMO site during summer stratification 1996: nominal size ranges $>10\mu\text{m}$ (A,B), $5- 10\mu\text{m}$ (C, D), $0.7- 5\mu\text{m}$ (E, F), and $< 0.7\mu\text{m}$ (G). Absorption coefficients at 440 nm measured on discrete water samples collected at locations indicated by dots

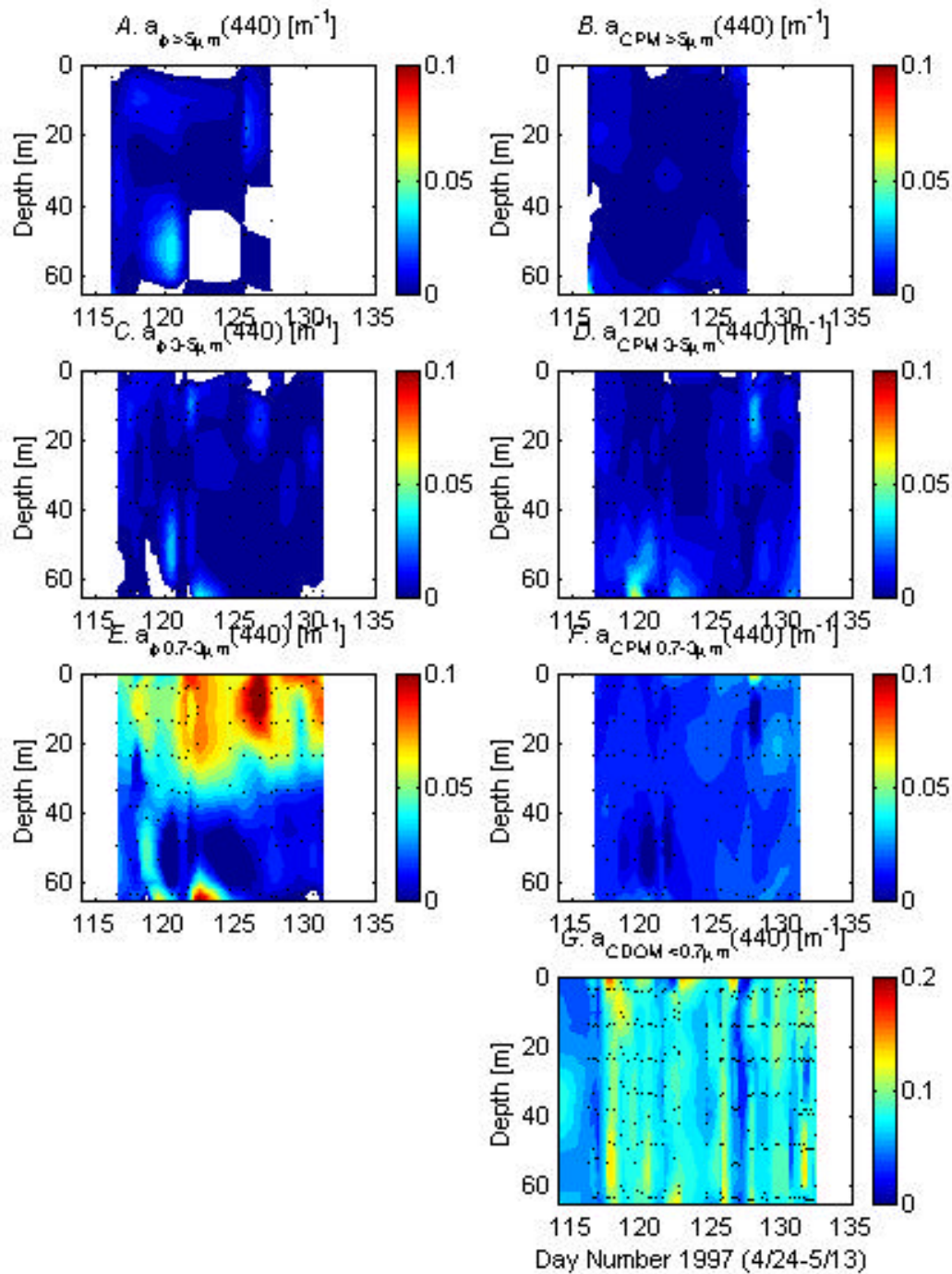


Figure 3. Size fractionated phytoplankton (left panel) and colored particulate and dissolved material (right panel) absorption at the CMO site during the onset of stratification in the spring of 1997: nominal size ranges $> 5 \mu m$ (A, B), $3-5 \mu m$ (C, D), $0.7-3 \mu m$ (E, F), and $< 0.7 \mu m$ (G). Absorption coefficients at 440 nm measured on discrete water samples collected at locations indicated by dots.